

## **Attachment 1: Description of Emission Reduction Measure Form**

*Please fill out one form for each emission reduction measure. See instructions in Attachment 2.*

**Title: Ammonia Fuel for Peaker Plants and Back-Up Electric Generators (9/29/07)**

**Type of Measure (check all that apply):**

- |   |   |
|---|---|
| <input type="checkbox"/> Direct Regulation  | <input checked="" type="checkbox"/> Market-Based Compliance |
| <input checked="" type="checkbox"/> Monetary Incentive                            | <input type="checkbox"/> Non-Monetary Incentive             |
| <input type="checkbox"/> Voluntary  | <input type="checkbox"/> Alternative Compliance Mechanism   |
| <input checked="" type="checkbox"/> Other Describe: <b>Technology Improvement</b> |   |

**Responsible Agency: ARB**

**Sector:**

- |   |  |
|---|--|
| <input type="checkbox"/> Transportation   | <input checked="" type="checkbox"/> Electricity Generation |
| <input type="checkbox"/> Other Industrial | <input type="checkbox"/> Refineries                        |
| <input type="checkbox"/> Agriculture      | <input type="checkbox"/> Cement                            |
| <input type="checkbox"/> Sequestration    | <input type="checkbox"/> Other Describe:                   |

**2020 Baseline Emissions Assumed (MMT CO<sub>2</sub>E): 2.5 MMT**

**Percent Reduction in 2020: 100%**

**Cost-Effectiveness (\$/metric ton CO<sub>2</sub>E) in 2020: \$6/MT CO<sub>2</sub>E initially, then decreasing to zero.**

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**Description:** California has almosts 30 peaker and back-up power plants in operation or planned.

[http://www.energy.ca.gov/maps/06\\_RONLN\\_APRVD\\_CUR\\_EXP\\_PEAKEER.PDF](http://www.energy.ca.gov/maps/06_RONLN_APRVD_CUR_EXP_PEAKEER.PDF).

These plants will operate on fossil fuels (natural gas and diesel) with a total capacity of over 5000 MW. At a nominal efficiency of 50% and a 10% duty cycle (only run 1/10 of the year), these plants will require the equivalent of 250 million gallons of gasoline per year to operate. Operating at that capacity, the combined generators will produce 2.5 million tons of CO<sub>2</sub> per year. By converting these facilities to operate on ammonia fuel, those CO<sub>2</sub> emissions can be reduced to zero.

Ammonia fuel (NH<sub>3</sub>) contains no carbon, and burns without any greenhouse gas emissions. Combustion products are simply nitrogen and water vapor. A natural gas combustion turbine or diesel engine (sparkless, combustion ignition) back up generator

can be converted to run on 95% ammonia plus 5% biodiesel or DME. The biodiesel and DME could be manufactured in a carbon neutral process.

**Emission Reduction Calculations and Assumptions:** Each gallon of gasoline or diesel fuel that is replaced by ammonia fuel saves 20-25 pounds (~10 kg) of CO<sub>2</sub> from being emitted into the atmosphere. For the 5000 MW of peaker/back-up power (assumed 50% efficient conversion) generation at 10% duty cycle, there will be 2.5 million tons of CO<sub>2</sub> emitted. By converting just these peaker/back-up facilities to operate on ammonia fuel, all of those emissions can be eliminated.

**Cost-Effectiveness Calculation and Assumptions:** A preliminary estimate for the cost for conversion of the combustion turbines (and in limited cases, diesel generator) generators for ammonia operation would be that each turbine/diesel generator engine should be able to be converted to operate on ammonia or ammonia-rich blend for nominally \$30,000 per MW capacity (this is consistent with other GHG reduction concepts submitted by this author (e.g. \$1500 for conversion of a nominal 50 kW automotive engine). Thus, in the case of the 5000 MW peaker/back-up capacity a total conversion cost would be approximately \$150 million. Assuming a useful life of 10 years for this conversion to ammonia fuel operation, that would be \$15 million for an annual reduction of 2.5 million MT of CO<sub>2</sub>. These costs would be expected to be borne by the power back-up/ companies or individual investors, not by the CA government or taxpayer. These conversion costs would of course be "one-time" and go away with the next generation of electric power back-up, which would be manufactured ammonia-ready.

There would also be a slight savings in fuel cost since ammonia fuel is approximately 2/3 the cost of gasoline or diesel on an equivalent energy basis.

**Implementation Barriers and Ways to Overcome Them:** The technology to operate internal combustion engines and combustion turbines on ammonia is proven and available. There appear to be no major obstacles to implementation.

**Potential Impact on Criteria and Toxic Pollutants:** In addition to emitting no CO<sub>2</sub>, combustion of NH<sub>3</sub> in engines produces no CO, no SO<sub>2</sub>, and no particulates. Lab results have shown that NO<sub>x</sub> emissions are reduced by 75% over an equivalent gasoline engine. But the situation is actually better than that, because NH<sub>3</sub> itself is the active ingredient in NO<sub>x</sub> treatment, so NO<sub>x</sub> emissions can be effectively reduced to zero.

It is also possible to capture the clean water vapor from ammonia fuel combustion process by simple condensation and return it to the domestic water supply. (This capability has been demonstrated for hydrogen engines and fuel cells by capturing the water for drinking purposes. The same is true with ammonia combustion.) Roughly 1 gallon of fresh water could be recovered for each gallon of ammonia fuel burned. This recovered water could be used for domestic needs. At a 10% duty cycle for the 5000

MW capacity analyzed here, the annual potable water recovered could be significant for domestic needs.

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